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Instruction Manual
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Phase and Motor Rotation Testers

Catalog No. 560060

Catalog No. 560400

U.S. Patent No. 2,566,726

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James G. Biddle Co.

PLYMOUTH MEETING, PA. 19462

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Foreword

The Biddle Phase and Motor Rotation Tester was developed as a practical answer to motor rotation problems.

This instrument eliminates the need for a temporary hookup to determine direction of rotation before final connection is made. Important motor installations may be permanently wired on a site before power is available. The installer can feel confident that when the power line is brought in and properly connected, all motors will run in the required direction.

This multi-purpose instrument will also determine the polarity of power and instrument transformers, and can be used as a continuity tester in checking electrical circuits.

Questions arising after study of this manual and use of the instrument will be welcomed. Write us and detail your problem clearly.

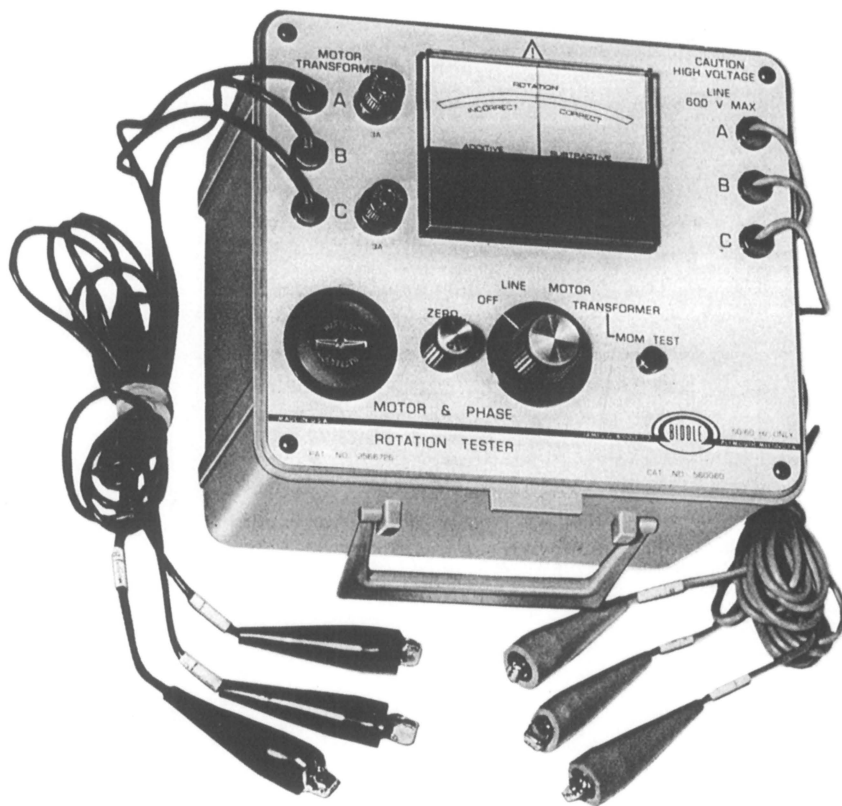


Figure 1. Phase and Motor Rotation Tester, Catalog No. 560060.

SECTION A:

Introduction

1. Purpose of Manual

This manual is published as a guide to the operation and maintenance of the Biddle Phase and Phase Rotation Tester. All the principles involved are fully explained but no attempt is made to treat every case that may arise.

Customers are invited to comment on this manual and to suggest applications which are felt to be of use to others in the field.

2. Purpose of the Tester

This Tester is used to identify the leads of a disconnected poly-phase motor so that when connected in true phase sequence it will run in the desired direction.

The Tester is also used to identify true phase sequence of energized ac power lines up to and including 600 volts.

Other uses include the determination of transformer polarity and testing of circuit continuity.

The above features also provide in a single instrument, facilities for identifying phase and polarity of winding sections of a multiple winding motor. Where connection diagrams are lost or terminal markings are obliterated, this identification process is necessary before a motor can be reconnected. The job is a difficult one at best, and increases in complexity as the number of windings increases. Representative cases are described in paragraphs 11, 12 and 13. The basic principles described can be extended to cover more complex cases. Fortunately, motor manufacturers are conscientious in following motor standards for permanently identifying such complicated windings and terminal arrangements.

3. General Description

The complete Tester is shown in Figure 1. The case is high impact ABS. It measures 9 x 7½ x 7½ inches with the removable cover closed. The complete Tester weighs approximately 3½ pounds.

Three red (Line) leads on the right may be connected to energized ac power systems up to 600 volts. These are 6 feet long. Each is terminated in a battery clip and protected with a red rubber boot. The leads are identified A, B, C at the instrument panel and

again at the clip. They are permanently attached to the panel assembly but may be readily replaced when necessary.

Three smaller black (Motor) leads on the left are for connection to de-energized equipment. These are 4 feet long and the battery clips are smaller. They are identified in the same manner as the line leads, using the same letters.

Three basic test circuits are incorporated in the Tester. One is an uncalibrated bridge used to determine the direction of motor rotation. The second is a phase sequence indicator of conventional design. The third is a simple polarity test circuit for transformer testing. A single zero center milliammeter serves as an indicator for all three circuits. A switch permits the selection of the desired circuit.

The source of energy for tests on de-energized equipment is a single flashlight battery.

Fuses are in series with the MOTOR A and C test leads as a protection for the operator should he accidentally touch these leads to an energized circuit.

SECTION B:

Operation

4. Controls and Connectors

Refer to figure 1 for location of the controls described below.

a. **MOTOR LEADS.** Three black leads marked A, B, C, are attached to the left of the panel. These are for use in testing motors, transformers and other de-energized equipment.

CAUTION - Never connect the black leads to an energized line or equipment

Failure to observe the caution above will result in damage to the Tester and endanger the operator. Fuses are connected in series with the A and C leads to protect the operator but these do not protect the Tester.

b. **LINE LEADS.** Three red leads marked A, B, C, are attached to the right of the panel. These are for use in testing energized ac or 50/60 Hz power lines at voltages up to and including 600 volts.

CAUTION

Use care when connecting red leads to energized circuits

c. **SELECTOR SWITCH (S_2).** A four position switch is used to turn the set on and select the desired circuit.

In the OFF position both the meter and the battery are disconnected from all circuits.

In the LINE position, the meter is connected in the phase sequence circuit and the LINE leads may be used to make a phase sequence measurement. The battery remains disconnected.

In the MOTOR position, the meter is disconnected from the phase sequence circuit and connected in the motor rotation circuit. The battery is also connected. The MOTOR leads may now be used for a rotation test.

In the TRANS position, the meter and battery are connected so that the MOTOR leads may be used for a transformer polarity test.

d. **ZERO ADJ. (R_1).** When the selector switch is in MOTOR position and the MOTOR leads are connected, this gives control of the meter deflection and may be used for balance in motor rotation tests.

e. **TEST ON RELEASE (S_1).** A push switch is connected in series with the battery. This opens the battery circuit when it is depressed.

f. METER (M_1). The meter is a zero center instrument with an ungraduated scale marked CORRECT on the right side and INCORRECT on the left. Below the scale the meter is marked SUBTRACTIVE on the right and ADDITIVE on the left.

g. FREQUENCY SWITCH (S_3). One model has a switch for the user to set in accordance with the line frequencies being checked.

5. Preliminary Check of Tester

Set the selector switch to MOTOR position. Connect the MOTOR lead marked A to the MOTOR lead marked B. Observe the meter. Operate the ZERO ADJ. control until pointer lies between the two R's in the word CORRECT. If no deflection is obtainable when attempting this test, the A lead fuse, F_1 , is open or the battery is completely dead.

When proper deflection is obtained connect the MOTOR lead marked C to the junction of the A and B leads. Observe the meter. With a fresh battery the pointer should deflect full scale to the left (INCORRECT). If the deflection is less than half scale (use the space between the two R's for reference) the battery should be replaced. If no change in deflection is noted when the C lead is connected, the C lead fuse, F_2 , may be open.

6. Motor Rotation, 3 Phase, 3 Terminal

Set the selector switch to MOTOR position. Connect the MOTOR leads to the three terminals of the motor in any order. Operate the ZERO ADJ. control to set the meter pointer at the center of the scale. Manually turn the motor shaft slightly in the desired operating direction. Observe the meter. The meter will deflect ("kick") in one direction then in the opposite direction.

**The first direction is significant
Ignore the second or opposite direction.**

If the first deflection is in the INCORRECT direction, reverse any two MOTOR leads. When the meter shows CORRECT deflection, tag the MOTOR leads according to the MOTOR lead markings (A, B, C).

Should it be difficult to distinguish clearly the first deflection because of a large second deflection, move the rotor a few degrees and repeat the test.

The initial deflection will always be in one direction corresponding to a given armature rotation which can be distinguished from possible false symmetrical oscillations that can occur if residual magnetism is present in the armature teeth. The false oscillations can be observed even without the presence of a dry cell or if the "TEST ON RELEASE" switch is not making contact.

7. Phase Sequence, 3 Phase

Set the selector switch to LINE position. Connect the red LINE leads to the 3 terminals of the line in any order. See paragraphs 4a and 4b. Observe the meter. If the meter reads INCORRECT, interchange any two of the LINE leads. When CORRECT reading is obtained tag the line terminals according to the LINE lead markings (A, B, C). Phases A, B, C now follow in true sequence.

8. Motor to Line Connection

When the motor terminals A, B, C are connected to corresponding line terminals A, B, C which were tagged in true phase sequence as described in paragraph 7, the motor will run in the direction in which it was turned as described in paragraph 6. To conform with NEMA MG1-2.20, the numbers 1-2-3 may be used in place of A, B, C. Note that there is no standard rotation for polyphase induction motors. To facilitate arrangement of leads, two alternate methods of connection are tabulated below.

<i>Motor</i>		<i>Line</i>		<i>Motor</i>		<i>Line</i>
A	to	B		A	to	C
B	to	C		B	to	A
C	to	A		C	to	B

9. Transformer Polarity—Single Phase

Set the selector switch to OFF position. Connect two adjacent high and low-voltage transformer terminals using a suitable jumper. Connect the C MOTOR lead to one of these terminals. Connect the B MOTOR lead to the remaining high voltage terminal. Connect the A MOTOR lead to the remaining low voltage terminal. Set the selector switch to TRANS position. Press the TEST ON RELEASE button and release. Observe the meter on release. Deflection of the meter indicates transformer polarity. Read either SUBTRACTIVE to the right, or ADDITIVE to the left. If sensitivity is not adequate on low ratio transformers, switch to MOTOR position without changing leads, operate ZERO ADJ. control to set pointer at center, then test as above.

When two adjacent terminals of adjacent coils are connected together the induced coil voltages or the terminal voltages will add in an additive transformer and subtract in a subtractive transformer.

10. Continuity

Set the selector switch to MOTOR position. Connect A and B MOTOR leads together. Operate ZERO ADJ. control until meter reads full scale. Use A and B MOTOR leads for testing continuity. Resistances in the order of 10 ohms or lower will not appreciably reduce the full scale reading of the meter. A resistance of 600 ohms will give approximately half scale deflection. Resistances above 20,000 ohms will show practically zero deflection.

11. Motor Connection, 9 Wire, 3 Phase, Dual Voltage, Single Speed

This and the following two paragraphs are not primarily concerned with the rotation of motors. Instead, they describe the use of the Tester in identifying polarity and phase of motor windings where the terminal markings have been destroyed, or where connection diagrams are lost.

The procedure is complicated and should be avoided whenever possible. For simplicity of presentation, the descriptions are restricted to the specific cases given in the paragraph headings.

Motors of the type considered here are representative of multiple winding motors in general, and the principles described will be of use on other motors of this general class.

The motor windings discussed may be connected in star as shown in figure 2a, or delta as shown in figure 2b.

The first step is to identify the windings by means of a continuity test such as described in paragraph 10. By this means the terminals can be grouped so that all terminals in a group show continuity to each other. The groups will have either two or three terminals. When three 3-terminal groups are found, the winding is delta connected. The groups can be seen in figure 2b. In the star connected case as shown in figure 2a, there are three 2-terminal groups and one 3-terminal group.

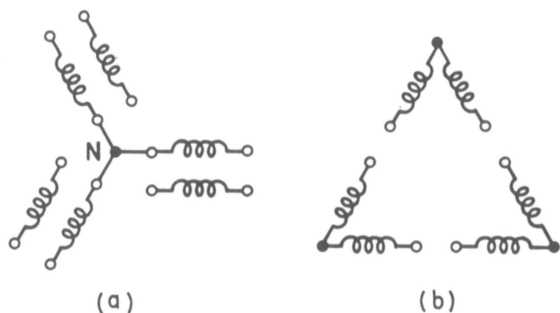


Figure 2. Coil Arrangements—9 Wire, 3 Phase Motors

12. Motor Connection, 9 Wire, 3 Phase, Dual Voltage, Single Speed, Delta Connection

In the delta connected winding, one terminal in each group is common to two winding sections. This terminal can be identified by using the motor rotation circuit as a bridge. Connect all three MOTOR leads together. Set the selector switch to MOTOR position. Operate the ZERO ADJ. control to bring the meter pointer to zero (center). Connect the three MOTOR leads to the three terminals of the group in any order. Observe the meter deflection.

Reverse the A and B MOTOR leads. Again observe the deflection. Reverse the B and C MOTOR leads. Note the deflection. Return to the connection that gave the smallest deflection of the meter. At this point the B MOTOR lead is connected to the common terminal. Now make a motor rotation test with the leads connected as above by rebalancing the Tester if necessary, using the ZERO ADJ. control, and then turning the motor slightly in the direction in which it is desired to run. If no preferred direction is specified, turn it clockwise when viewed from the drive end. If the deflection is in the INCORRECT direction, reverse MOTOR leads A and C. When the CORRECT deflection is obtained, the terminals in the group should be marked according to the MOTOR lead markers. The number 1 should be used as a prefix to identify the group. Thus, the terminal connected to the A MOTOR lead is marked 1A. The common terminal is marked 1B, and the remaining terminal 1C.

Select a second group of leads. Determine the common terminal and rotation in the same manner as described above. In tagging these terminals the prefix number is temporarily omitted. The terminals are tagged A, B, C. If done properly B will mark the common lead. At this stage the identification of terminals has reached the stage shown in figure 3. It remains to be determined whether this second group belongs in the 2 or 3 position. This can be determined by an induced voltage test which indicates whether coil A-B

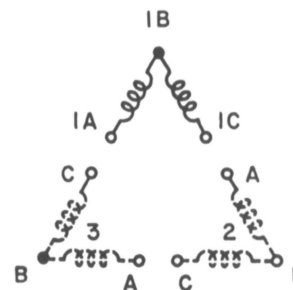


Figure 3. First Section Identified, 9 Wire, 3 Phase, Delta, Motor

or coil B-C is in phase with coil 1B-1C. This is accomplished as shown in figure 4. Connect the MOTOR A lead to terminal 1B. Connect the MOTOR C lead to terminal B (second group). Connect the MOTOR B lead to terminal 1C. Connect a jumper from terminal 1C to terminal A (second group). Set the selector switch at MOTOR position, operate the ZERO ADJ. control to balance the meter. Now test by pressing the TEST ON RELEASE button and note the meter "kick" on release. Change the jumper from A terminal to C terminal. Repeat the test. Return to the jumper con-

nection which gives the greatest "kick." If this is the A connection as shown in figure 4a, mark a prefix 2 in front of all three terminals in the second group. If the C jumper connection gives the greater "kick" (figure 4b) use a prefix 3. Remember that the group shown in position 3 (figure 4b) is the same group shown in position 2 (figure 4a). It is shifted to position 3 only in the event the C jumper connection gives the greater "kick."

Finally, determine the common lead and rotation for the third group using the same methods described above. Tag these A, B, C as described, but prefix them with the remaining number, either 2 or 3, whichever was not used to mark the second group. Figure 2b may now be redrawn with all terminals identified as shown in figure 5. The motor may be connected for either low voltage or high voltage according to Table I.

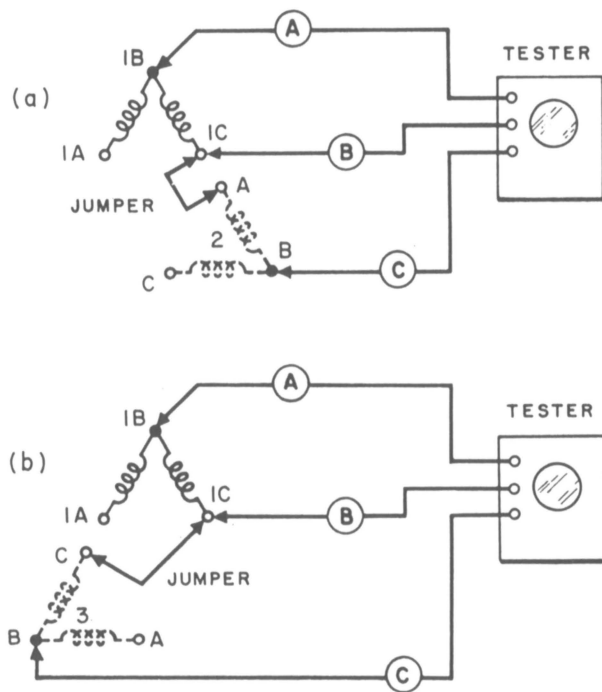


Figure 4. Identification of Remaining Sections, 9 Wire, 3 Phase, Delta, Motor

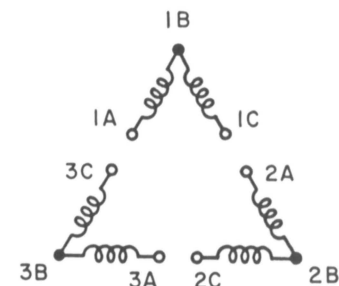


Figure 5. Complete Identification, 9 Wire, 3 Phase, Delta, Motor

TABLE I

	Connect	Line
Low Voltage	1A - 3B	1B, 2B, 3B
	3C - 1B	
	1C - 2B	
	2A - 1B	
	3A - 2B	
	2C - 3B	
High Voltage	1A - 3C	1B, 2B, 3B
	2A - 1C	
	3A - 2C	

As a result of the motor rotation tests made during the terminal identifications, the rotation of the motor is known without further tests. When the motor is connected as described in paragraph 8 it will run in the direction in which it was turned during the tests described in paragraph 12. In making such a connection terminal 1B is thought of as A, terminal 2B as B and terminal 3B as C.

13. Motor Connection, 9 Wire, 3 Phase, Dual Voltage, Single Speed, Star Connected

The four separate winding groups were established as explained in paragraph 11. The next step is to pair phase sections in a manner similar to that required in the delta case. Each of the three 2-terminal groups must be paired with the proper leg of the 3-terminal star group. For convenience, it is desirable to identify the three terminals of the star group. A rotation test can be made at this time using the MOTOR leads on the three star terminals. Follow the procedure in paragraph 6 until a CORRECT signal is obtained.

If no specific direction of rotation is required, turn the rotor clockwise when viewed from the drive end. Mark the terminal connected to the A MOTOR lead 1. Mark the terminal connected to the B MOTOR lead 2. Mark the other terminal 3.

The pairing is done as in the delta case by energizing two phase sections with the A and C MOTOR leads and searching for minimum inductive pickup among the three separate winding sections by means of a jumper and the B MOTOR lead. This method is shown in figure 6. Three steps are required. First, connect the A

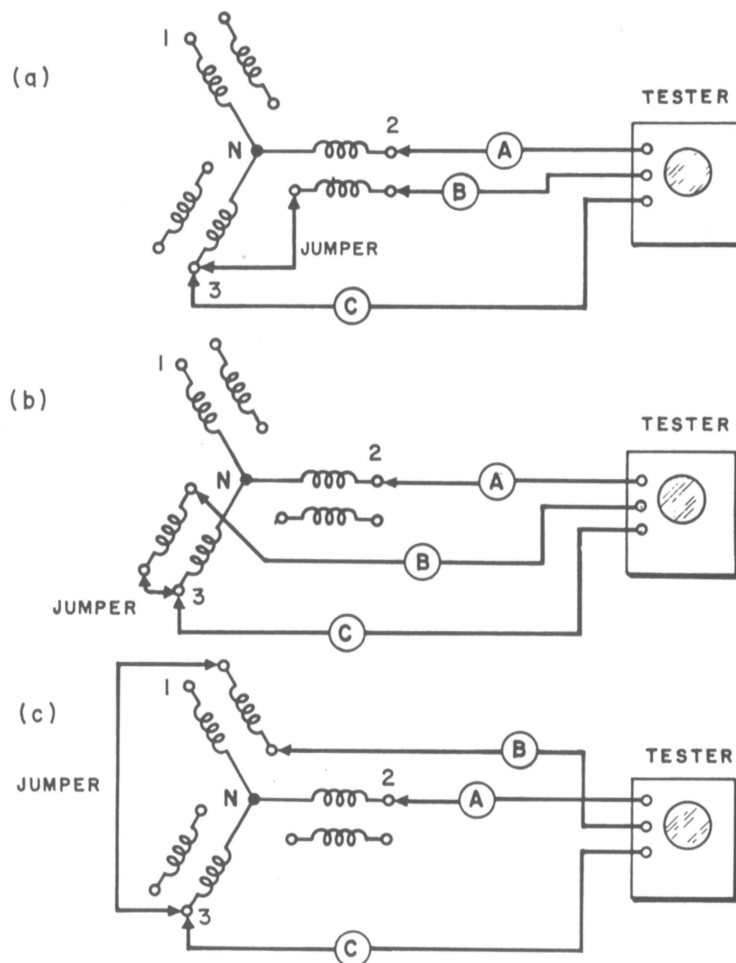


Figure 6. Test for Pairing Phase Sections, 9 Wire, 3 Phase, Star, Motor

MOTOR lead to terminal 2 of the 3-terminal group. Connect the C MOTOR lead to terminal 3 of the group. Also connect a jumper to terminal 3. Connect the B MOTOR lead and the other end of the jumper to the terminals of any 2-terminal group as shown in figure 6a. Switch to MOTOR position. Balance using the ZERO ADJ. control. Operate the TEST ON RELEASE button. Note meter "kick" on release. If it is not possible to balance the meter exactly, the meter will go to zero when the button is pushed and return to the balance position upon release. The "kick" will be superimposed on this deflection.

Transfer the B MOTOR lead and jumper to the terminals of a second 2-terminal group as shown in figure 6b. Repeat the test, noting the deflection as before.

Again transfer the B MOTOR lead and jumper to the last group as in figure 6c. Again repeat the test, noting the "kick." Return to the connection which gives the smallest CORRECT or INCORRECT meter "kick." Mark X on each of the terminals of this connected 2-terminal group. The X-X winding section is in phase with the unused branch (1) of the star group.

Now connect the A MOTOR lead to terminal 1, and C MOTOR lead to terminal 3. Also connect the jumper to terminal 3. Use the other end of the jumper and the B MOTOR lead to test each of the remaining 2-terminal groups in the manner described above. The group which shows the least "kick" is in phase with the unused branch (2) of the star group. Mark each terminal Y.

The remaining 2-terminal group must now be in phase with the remaining branch (3) of the star group. Mark each of its terminals Z. Figure 2a may now be redrawn as shown in figure 7.

At this point in the test the 2-terminal groups have been paired with the proper phase legs of the star 3-terminal group, but the polarity of these three 2-terminal groups with respect to their paired star legs must now be determined.

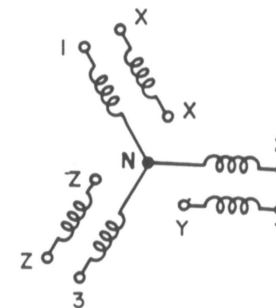


Figure 7. Phase Sections Identified, 9 Wire, 3 Phase, Star, Motor

To determine the polarity of X-X with respect to 1-N, the MOTOR leads may be connected as shown in figure 8 and tested as described above, using the MOTOR circuit and the TEST ON RELEASE button. The "kick" should be noted as the button is released. If the "kick" indicates SUBTRACTIVE polarity (to the right) then the X terminal attached to the B MOTOR lead becomes X1 and the other X terminal (attached to the jumper) becomes XN. If the "kick" indicates ADDITIVE polarity, then the terminal attached to the B MOTOR lead becomes XN and the other becomes X1.

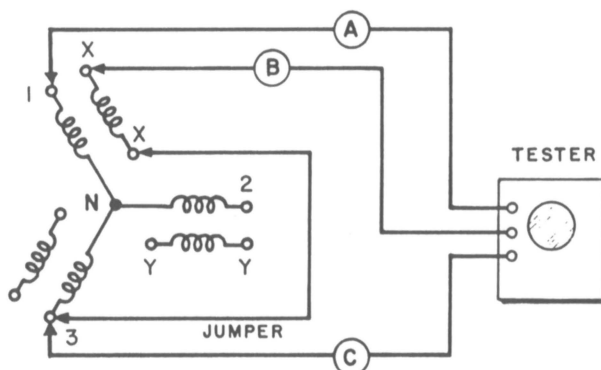


Figure 8. Polarity of Phase Sections, 9 Wire, 3 Phase, Star, Motor

The other two phase polarities are determined in the same manner after which a completed connection diagram can be drawn as shown in figure 9. The motor may then be wired according to Table II.

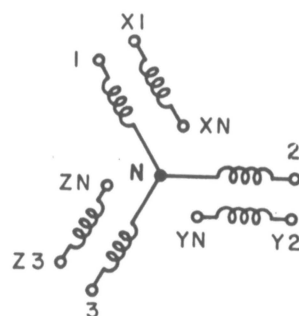


Figure 9. Complete Identification, 9 Wire, 3 Phase, Star, Motor

TABLE II

	Connect	Line
Low Voltage	X1 - 1	
	Y2 - 2	1, 2, 3
	Z3 - 3	
	XN - YN - ZN	
High Voltage	XN - 1	
	YN - 2	X1, Y2, Z3
	ZN - 3	

The motor rotation was determined as one of the first steps. When the motor is connected as described in paragraph 8, it will run in the direction in which it was turned during the foregoing tests. In making such a connection, terminal 1 or X1 is thought of as A, terminal 2 or Y2 as B and terminal 3 or Z3 as C.

14. Phase Sequence, 3 Phase, Above 600 Volts

Potential transformers are required for measurements on systems above 600 volts. The reliability of a phase sequence measurement under these conditions is greatly improved by a straightforward transformer connection as shown in figure 10.

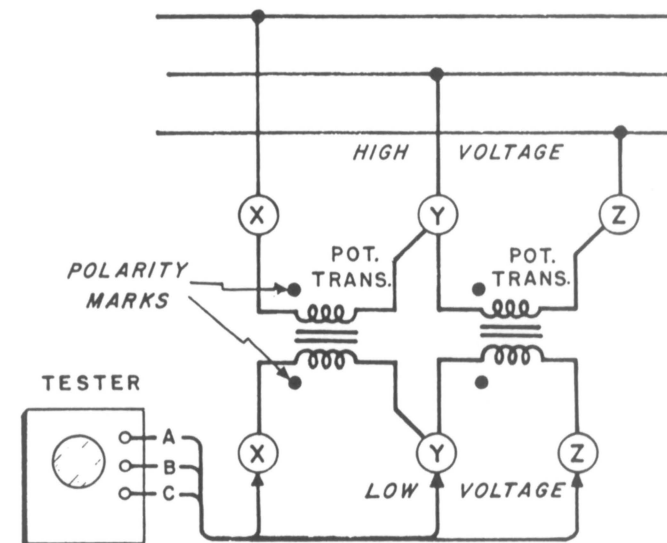


Figure 10. Connection of Potential Transformers for Phase Sequence above 600 Volts

If the polarity marks on the transformers are in doubt, make a test as described in paragraph 9, connecting the A and B MOTOR leads to the transformer terminals having polarity marks, and the C MOTOR lead to the junction of the remaining transformer terminals. If the meter shows SUBTRACTIVE polarity when the TEST ON RELEASE button is released, the polarity marks are correctly placed.

When the transformers are connected and the line energized, make a phase sequence measurement as described in paragraph 7, using the low voltage terminals marked X, Y, Z in figure 10. Both X terminals may now be tagged with the letter (A, B or C) on the MOTOR lead which is connected to the low voltage X terminal. The same procedure holds for the Y and Z terminals. A motor may now be connected to the high voltage system as described in paragraph 8.

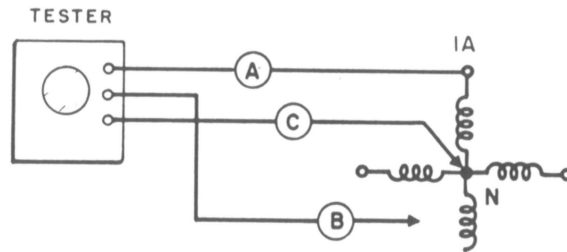


Figure 11. Test for Phase Sequence, 2 Phase, 5 Wire System

15. Phase Sequence, 2 Phase, 5 Wire

Read paragraphs 4, 5 and 7. Set the selector switch to LINE. Connect the C LINE lead to neutral (ground) of the system. Arbitrarily select one of the remaining four leads and tag it 1A. Connect the A LINE lead to this terminal as shown in figure 11.

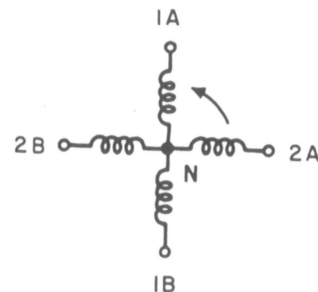


Figure 12. Phase Sequence, 2 Phase, 5 Wire System

Connect the B LINE terminal to each of the three remaining terminals in turn. Note the meter deflections in each case. One will be INCORRECT, one will be CORRECT and the third will be between the two extremes. Tag the terminal corresponding to the CORRECT deflection 2A. Tag the INCORRECT terminal 2B. Tag the terminal corresponding to the middle deflection 1B. The system is now as shown in figure 12. The phases follow each other in the order 1A, 2A, 1B, 2B.

This can be seen by comparing sections 1A-N and 2A-N which are 90 degrees apart to an open delta system in which the angle is 60 degrees instead of 90. For angles less than 180 degrees, any difference in angle only affects the amplitude of signal but not the direction. See figure 15. It follows that when the A LINE lead is connected to terminal 1A, B to 2A and C to N, the phase 2A-N follows 1A-N if a CORRECT reading is obtained. By the same reasoning an INCORRECT reading is obtained when the B LINE lead is transferred to terminal 2B. When B LINE lead is moved to terminal 1B the angle becomes 180 degrees. This theoretically should reduce the signal to zero amplitude, but practically because of component unbalance in the tester and voltage unbalance in the line there may be a small signal of unpredictable direction.

16. Motor Rotation, 2 Phase, 4 Wire

To test the rotation of a 4 wire, 2 phase motor, first find the two terminals common to one winding. To do this use the continuity test described in paragraph 10. Mark these terminals 1A and 1B.

Connect the C MOTOR lead to terminal 1A and the B MOTOR lead to terminal 1B. Also connect one end of a jumper to terminal 1B. Connect the second end of this jumper to one of the two remaining motor leads. Connect the A MOTOR lead to the last remaining MOTOR lead. Make a rotation test as described in paragraph 6. Interchange the A MOTOR lead and the second end of the jumper if necessary to obtain CORRECT rotation.

Now mark the terminal to which the A MOTOR lead is connected 2A. Mark the jumper terminal 2B.

If the motor is to be operated at half the system voltage connect terminals 1B and 2B to the neutral. Connect the other terminals, 1A and 2A, to corresponding terminals as determined by the sequence test of paragraph 15.

For operation at full system voltage connect all four terminals, 1A, 2A, 1B and 2B, to corresponding terminals of the line as determined in paragraph 15.

17. Single-Phase Motors, Split-Phase

Single-phase motors of the split-phase type are constructed with an auxiliary winding which is placed 90 electrical degrees from the main winding. This gives a two-phase winding which can be used for

starting. The phase angle of current in the auxiliary winding is caused to lead approximately 90° by making use of series reactance. In the common split-phase type the auxiliary winding has a higher resistance and higher ratio of resistance to inductance than the main winding. This causes the main winding current to lag behind the current in the auxiliary winding. Thus, the applied sequence is always: auxiliary winding then main winding. To test rotation, connect the A MOTOR lead to one terminal of the main winding. Connect the B MOTOR lead to the other terminal of the same winding. Also connect this to one terminal of the auxiliary winding with a jumper. Connect the C MOTOR lead to the remaining auxiliary terminal. Make a rotation test as described in paragraph 6.

The direction that results in a CORRECT deflection is the direction in which the motor will run when connected to the line. If reverse direction is desired, reverse the auxiliary winding by transferring the jumper from one auxiliary terminal to the other. When desired rotation is obtained, join permanently the two terminals that are connected by the jumper. Also, join the remaining two terminals. Connect each junction to one side of the line.

In many split-phase motors a capacitor is used in series with the auxiliary winding. As in the above case, the main field lags the auxiliary. The rotation test is made as above. In practice the two fields will usually be found connected for a standard rotation. The common connection being a terminal stud, no jumper is needed. It is not necessary to disconnect the capacitor to make a test.

Where a split-phase motor of the resistance or reactor-start type has no identification, it is possible to identify the auxiliary winding by the fact that it has higher resistance. To do this, identify the terminals of the individual windings by a continuity test as described in paragraph 10. Next connect one terminal of each winding with a jumper. Connect the B MOTOR lead to the junction. Connect A and C MOTOR leads to the junction and operate the ZERO ADJ. control to bring the meter to zero. Re-connect the A MOTOR lead to one of the free winding terminals and re-connect the C MOTOR lead to the other free terminal. If the meter deflection is INCORRECT reverse the A and C MOTOR leads. When CORRECT deflection is obtained, the winding connected to the C MOTOR lead has higher resistance and is therefore presumably the auxiliary winding. As a further check, if possible, operate the centrifugal switch manually. This will cause increased deflection in the CORRECT direction. Note that at this point the MOTOR leads are correctly connected for a rotation test.

SECTION C:

Theory Of Operation

18. Motor Rotation Circuit

When direct current is applied to the windings of a polyphase induction motor, a field is set up and the rotor iron becomes magnetized. If the magnetized rotor is turned, the field will rotate with it for a short time because of hysteresis in the iron. The motion of this field induces voltage in the windings. The direction of the induced voltage depends on the direction of rotation. The same factors that determine the direction of a rotating field in a connected motor determine the direction of voltage induced when the motor is manually turned while connected to the motor rotation circuit. The motor rotation circuit makes use of the above principles in order to determine motor rotation.

The circuit is a bridge in which two adjacent phase sections of the motor winding are balanced against a potentiometer. The simplest case where each phase section is a single coil side is shown in figure 13a. With the rotor at rest, the ZERO ADJ. potentiometer, R1, is adjusted to give zero current in the meter M1. At this point there is equal voltage across each of the two phase sections.

When direct current enters one phase (at terminal C) and leaves the adjacent phase (at terminal A) a field will be set up as shown by the air gap arrows in figure 13a. Now when the rotor is turned so that it moves from the one phase toward the adjacent phase, a voltage will be induced in the one phase that is opposite in direction to the direct current. A voltage will also be induced in the adjacent phase but this will be in the same direction as the direct current. Where the induced voltage is opposite to the direct current, it reduces the total voltage across the phase. Where induced voltage is in the same direction as the direct current, it adds to the phase voltage. Since the phase voltages were balanced before rotation, the induced voltages adding to one phase and subtracting from the other, cause an unbalance of the circuit. The unbalance voltage drives current through the meter in the positive direction and therefore causes a CORRECT reading.

If the motor were connected to a polyphase power system so that A phase follows C phase (sequence A, B, C) the rotor would also move in the same direction as just described. Thus the motor tagging, when CORRECT deflection is obtained, indicates the proper phase connections. To show how this simple theory is applied to

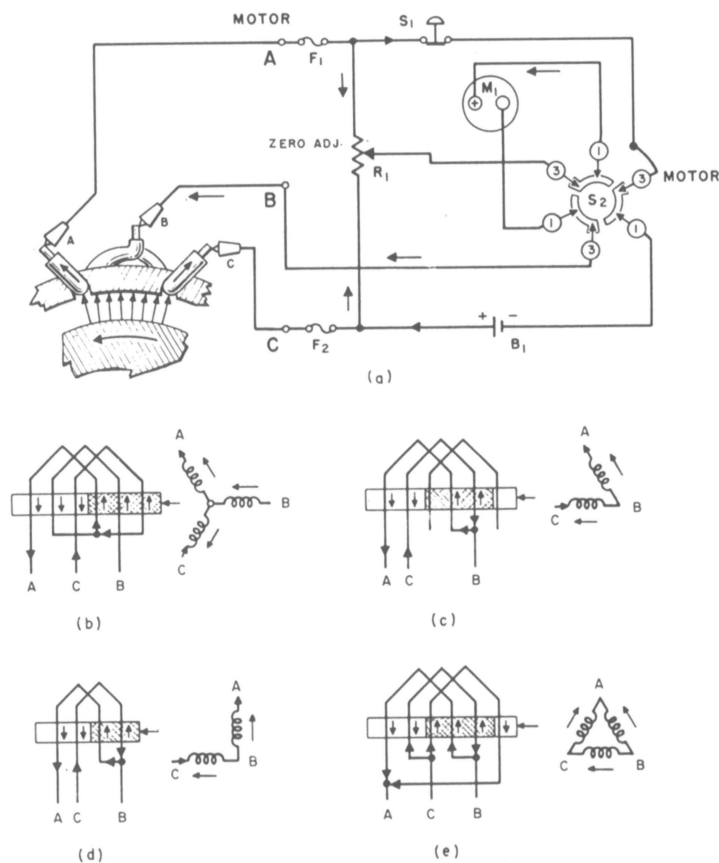


Figure 13. Motor Rotation Circuit

more complex windings, consider a two pole, three phase, star connected motor reduced to its simplest form in which all the coils of one phase group are represented by a single coil located at the center of the phase group which it represents. A developed view of the winding is shown in figure 13b. Also shown is the schematic coil arrangement. In all diagrams in figure 13, the direction of applied d-c is indicated by arrow heads on the wiring. Direction of induced voltages is indicated by arrows parallel to the wiring. In figure 13b the rotor surface is represented by the rectangle. Flux is shown as being distributed over the entire rotor surface in order to show the effect of a distributed winding. The shaded portion indicates flux entering the rotor. Unshaded area shows flux leaving. No indication of flux magnitude is necessary, but it may be noted that the magnitude is zero at the point where reversal takes place. This null

point in the field is found at the mid-point of any group of conductors carrying current in the same direction. The arrow at the side of the rectangle indicates the direction of motion of rotor and flux.

Figure 13c shows an open delta connection of coils on a three-phase motor. Figure 13d shows a two-phase motor. Figure 13e shows a three-phase delta connected motor.

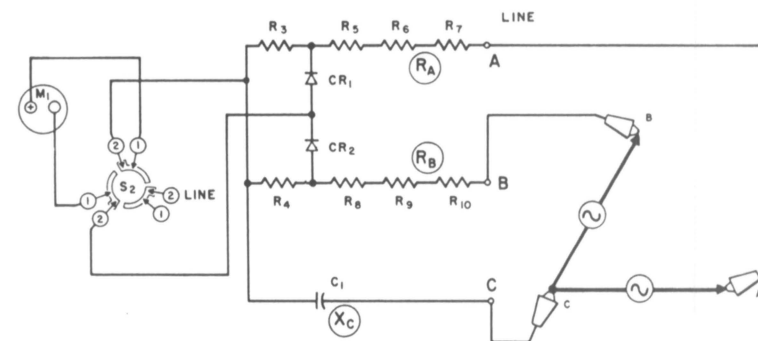


Figure 14. Phase Sequence Circuit

19. Phase Sequence Circuit

The phase sequence circuit is shown in figure 14. It consists of two series of resistors, R_A and R_B , and a capacitor X_C , joined together at one end to form a star connected network. Two rectifiers and a meter are connected part way out each resistance branch in such a way that whenever the voltage across resistor R_A is greater than that across R_B , the meter deflects to the right (CORRECT). The total resistance in each arm is 100,000 ohms and the capacitor arm reactance is also approximately 100,000 ohms at 60 Hertz or the selected frequency on sets having selectable frequency.

In operation, the circuit is connected to three terminals of a polyphase system in such a manner that the magnitude of the voltage applied to terminals C, B is very nearly the same as that applied to terminals C, A. The relative magnitude of voltages across R_A and R_B will then be determined by the phase angle between C, B and C, A as shown in figure 15. In the figure, the magnitude and direction of the applied voltages are shown by the location of a point identified by the terminal letter. The voltages across the network arms are also represented to scale. Positive or leading angles are measured in a counterclockwise direction. For the constants given above, the voltage vector from terminal C to the neutral point N is given by the following equation where the magnitude of the

applied voltages is unity. The phase angle is Z .

$$C - N = \frac{2 + 2 \cos Z + \sin Z}{5} + j \frac{2 \sin Z - \cos Z - 1}{5}$$

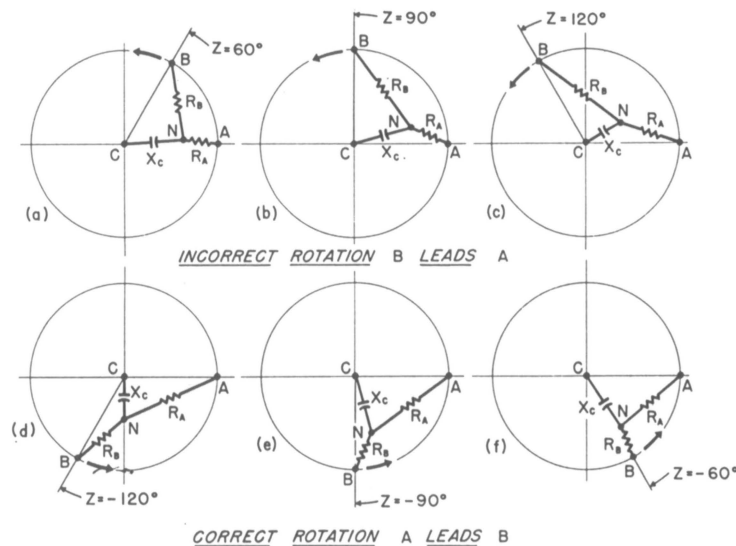


Figure 15. Vector Diagram of Phase Sequence Circuit

Figure 15a shows the INCORRECT rotation on a three phase system. Note that the magnitude of the voltage across R_B is greater than that across R_A . From a study of figure 14, it will be seen that a negative or INCORRECT meter deflection will be obtained. The term INCORRECT is used to describe a system in which the marked phases do not follow alphabetical sequence. Note that as the diagram is rotated in the leading direction B leads A. For CORRECT sequence B should follow A as in figure 15f. Figure 15b shows a two-phase system. Figure 15c shows the use of two line leads and neutral of a three-phase system. When the angle Z approaches 0 or 180 degrees, the difference in voltage across R_A and R_B is so small that tolerances in the components or voltage unbalance in the system may cause a spurious reading. This condition is never important in practical testing of two and three-phase systems.

20. Transformer Polarity Circuit

If direct current is suddenly applied to one winding of a transformer, a voltage will be induced in each of the other windings. When current flows in at a polarized terminal of one winding, induced current in any other winding will flow out at the terminal

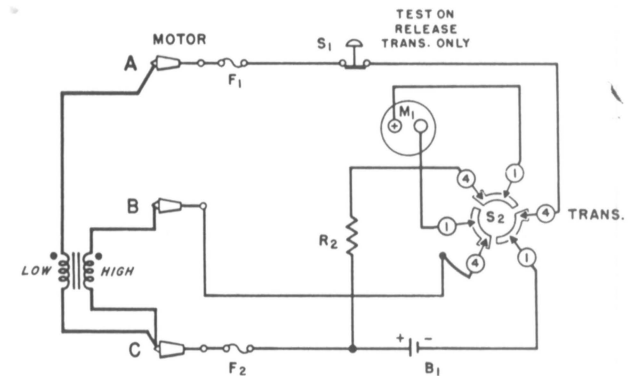


Figure 16. Transformer Polarity Circuit

having the same polarity. In polarizing windings it is sufficient to identify only one end. When this is done the mark is called a polarity mark. On schematic diagrams the mark is usually indicated by a dot near one end of the winding.

The transformer polarity circuit is shown in figure 16. It provides a battery as a source of direct current, and a meter for indicating the direction of induced current. A pushbutton, TEST ON RELEASE, is for convenience in testing. Note that on release the battery is connected.

When terminals having the same polarity are located adjacent to each other, joining the terminals will cause the voltages in each winding to buck or subtract. Transformers so arranged are said to be subtractive. Similarly, when adjacent terminals have different polarities, the arrangement is said to be additive. If adjacent terminals are connected to the C MOTOR lead when testing, the meter deflection will indicate whether the transformer is ADDITIVE or SUBTRACTIVE.

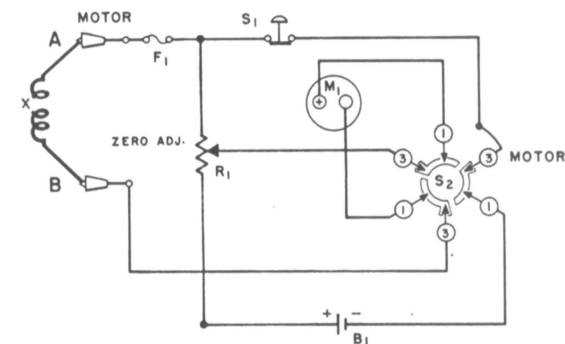


Figure 17. Continuity Circuit

21. Continuity Circuit

Figure 17 shows part of the MOTOR circuit used for testing continuity. The circuit is self explanatory.

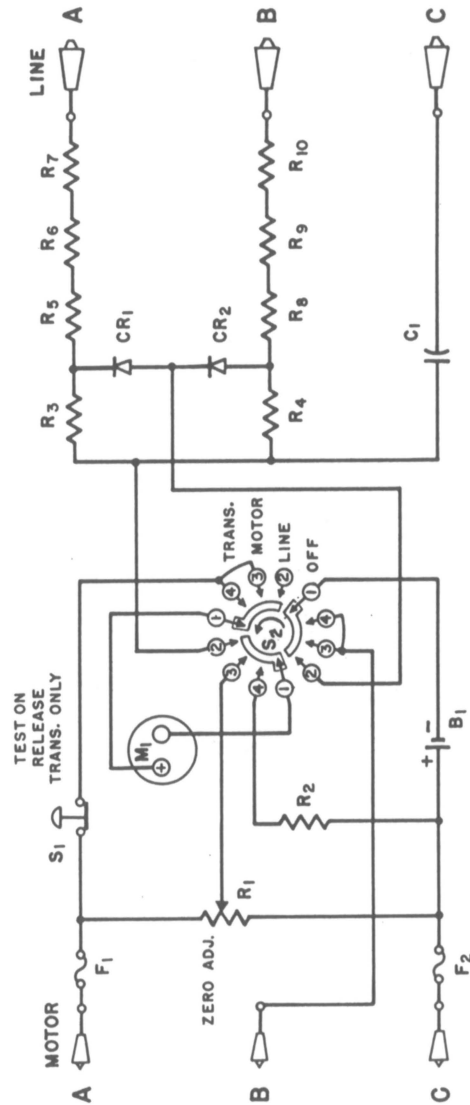


Figure 18: Schematic Diagram for Cat. No. 560060

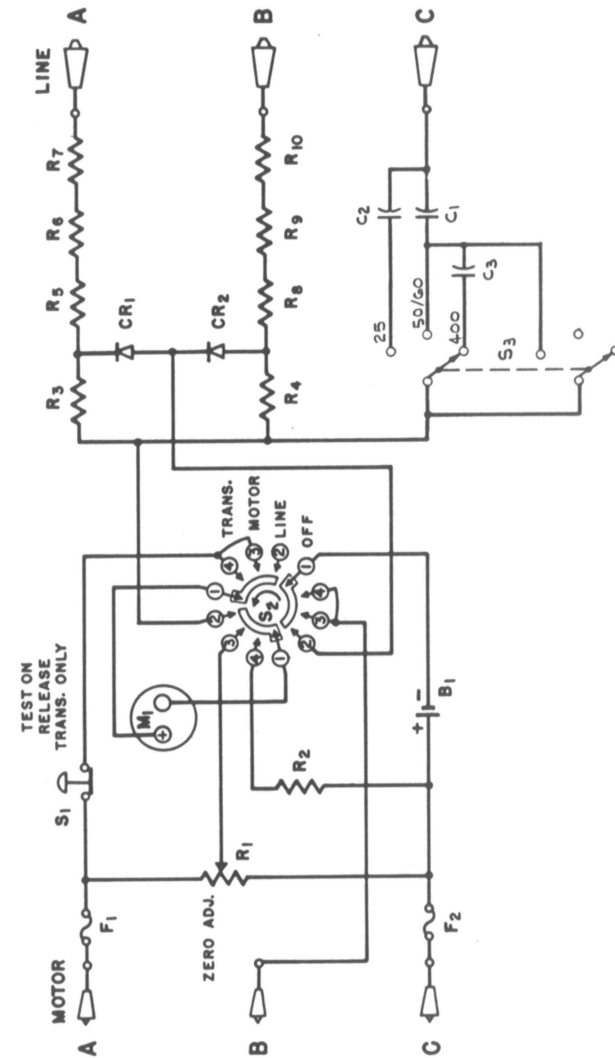


Figure 19: Schematic Diagram for Cat. No. 560400

SECTION D:

Maintenance Instructions

22. General

The useful life and reliability of this Tester will depend on the kind of treatment it receives from the user. However, even with the best of care, parts will wear out. In this Tester part replacement does not require more than ordinary skill. The paragraphs below describe the important considerations involved in the repair or replacement of the major components of the Tester. For guidance, complete schematic diagrams are shown in Figures 18 and 19.

23. Battery

Except for cases where the Tester is in every day use, the battery will probably last at least three months. Unless the battery is known to be fresh, it should be tested before use by the method described in paragraph 5. The button contact on the head end of the battery is positive. Its correct connection is indicated on the schematic diagrams. Use a Burgess No. 2, size D or equivalent standard flashlight cell.

24. Leads and Clips

Aside from the battery, the leads and clips are most likely to need replacement in the normal use of the Tester. Follow the wiring diagram carefully when attempting to repair or replace leads. Be careful in the arrangement of LINE leads particularly where the Tester is to be used on 600 volt lines.

Insulators on the LINE leads should be given extra attention. At the slightest sign of wear or deterioration, they should be replaced since they are the sole protection against contact with the live line.

Replacement parts are listed in paragraph 28.

25. Meter

The meter should not need replacement except as a result of abuse or careless handling of the Tester. It is a zero center d-c microammeter having a sensitivity of 1 ma full scale ($\frac{1}{2}$ ma each side). As in the case of other components, polarity is extremely important. Refer to the schematic diagram when replacing the meter. In emergency a standard one milliampere meter may be used.

26. Fuses

When replacing fuses, be sure that the contacts are clean and bright both on the fuse itself and on the fuse clips in the set. Erratic contact at the fuses will cause unsatisfactory performance of the Tester. Standard 250 volt, 3 ampere, fuses may be used for replacement.

27. Rectifier

Test the rectifiers occasionally by switching to LINE position and connecting the A and B LINE leads to a 115 volt, 60 Hertz system. The meter should deflect.

28. Replacement Parts List

Those parts which may be replaced in the field are stocked in small quantities. When ordering use the part number and description listed below. Certain of these items are generally available; these are completely described and marked with an asterisk. It is recommended that users obtain these parts from local suppliers or from the listed manufacturer. (See page 34)

29. Warranty

All products supplied by the James G. Biddle Co. are warranted against all defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair will be shipped prepaid and insured. The warranty does not include batteries, lamps or tubes, where the original manufacturer's warranty shall apply. WE MAKE NO OTHER WARRANTY.

The warranty is void in the event of abuse or failure by the customer to perform specified maintenance as indicated in the manual.

30. Repairs

The James G. Biddle Co. maintains a complete instrument repair service. Should this instrument ever require repairs, we recommend it be returned to the factory for repair by our instrument specialists. When returning instruments for repairs, either in or out of warranty, they should be shipped Prepaid and Insured, and marked for the attention of the Instrument Service Manager.

Replacement Parts List

		<i>J.G.B. Co.</i>
<i>Designation</i>	<i>Description</i>	<i>Part No.</i>
	Case Assembly	10998
	Cover	10997-7
	Instruction Sheet	15587
	Battery Holder	3274
B1	*Battery, See Paragraph 23	8857
CR1, CR2	Rectifier IN4004	11637-34
R3, R4	*Resistor, Fixed Comp., 820 Ohms $\pm$ 10% 1/2 W	4501-141
R2	*Resistor, Fixed Comp., 6800 Ohms $\pm$ 10% 1/2 W	4501-209
R5, R6, R7, R8, R9, R10	*Resistor, Fixed Comp., 33,000 Ohms $\pm$ 10% 2W	4501-451
R1	*Zero Adj. Potentiometer, 3000 Ohms 2W	5667-6
S1	*Switch, Pushbutton	5431
S2	Selector Switch	15586
S3	Selector Switch	1524-1
M1	Meter	15592
C1	*Capacitor, 2000 Volts, 0.033 MFD	8885-7
F1, F2	*Fuse, See Paragraph 26	2567-18
	Line Lead Assembly	8893
	*Line Lead Wire No. 18 AWG	8894-1
	*Line Clip, Mueller Electric Cat. 27	8895
	*Line Insulator, Mueller Cat. 29	2797-1
	Line A Marker	8853-1
	Line B Marker	8853-2
	Line C Marker	8853-3
	Motor Lead Assembly	8889
	*Motor Lead Wire, No. 18 AWG	1164-2
	*Motor Clip, Mueller Electric Cat. 48C	8891
	*Motor Insulator, Mueller Electric Cat. 49	8892-2
	Motor A Marker	8853-4
	Motor B Marker	8853-5
	Motor C Marker	8853-6
C2	Capacitor, 2000 Volts, 0.005 MFD	8885-2
C3	Capacitor, 2000 Volts, 0.004 MFD	8885-3